IN THE SPECIFICATION:

Please replace paragraph number **[0005]** with the following rewritten paragraph:

[0005] Another response has been the development of a so-called ball grid array ("BGA") semiconductor package that "surface mounts" and electrically connects to an associated carrier substrate, e.g., a printed circuit board ("PCB"), with a plurality of solder balls in a method sometimes referred to as the "C5" method that is analogous to the flip-chip method described above for mounting and connecting ~~dies.~~ dice.

Please replace paragraph number **[0007]** with the following rewritten paragraph:

[0007] In a solder-mask-defined ("SMD") solder ball pad, an aperture formed in the mask over a terminal pad defines the solder ball pad mounting area. Typically, the terminal pad comprises a layer of metal, e.g., copper, aluminum, gold, silver, nickel, tin, platinum, or a multilayer combination of the aforementioned materials that has been laminated and/or plated on a surface of the substrate sheet and then patterned using known photolithography techniques. Further, one or more circuit traces may be formed simultaneously with the terminal pads using the same processes. In addition, a plated through-hole, called a "via," may also be formed and may connect the pad layer with the opposite surface of the substrate sheet.

Please replace paragraph number **[0012]** with the following rewritten paragraph:

[0012] The SMD solder ball pad also affords relatively better control of the lateral (x-y) position of the solder ball on the surface of the substrate than does an NSMD solder ball pad. This is because the lateral position of the solder ball on the substrate may be affected by two factors: 1) the position on the substrate of the centroid of the aperture in the solder mask, if the vertical wall of the aperture interacts (e.g., touches, or electrostatically interacts) with the solder ball, and 2) the position of the centroid of the area of the metal pad layer that is exposed by the opening in the mask, i.e., the area wetted by the molten solder of the solder ball when the latter is attached to the solder ball pad. In both instances, the center of gravity of the solder ball tends to

align itself over each of the two respective centroids if both factors apply. As a result, when the centroid of the aperture does not coincide with the centroid of the exposed area of the mounting pad and the vertical wall of the aperture interacts with (~~e.g.~~ e.g., touches) the solder ball, the center of gravity of the solder ball may be positioned approximately half way along a line extending between the two centroids. Since in an SMD solder ball pad the aperture in the solder mask exposes only pad layer metal, the centroid of the aperture and exposed metal pad layer coincide. Thus, so long as the aperture in the solder mask is located within the periphery of the metal pad layer, the lateral tolerances of the SMD solder ball will depend substantially on the lateral positional tolerances on the centroid of the aperture.

Please replace paragraph number **[0016]** with the following rewritten paragraph:

[0016] U.S. Patent No. 6,201,305 to Darveaux et ~~al.~~ al., as well as U.S. Patent No. 5,872,399 to ~~Lee~~ Lee, each describes a solder ball pad structure. More specifically, the Darveaux reference describes an NSMD-type solder ball pad structure wherein a layer of metal on the substrate is formed into a terminal pad, the pad having at least two spokes radiating outwardly ~~from it.~~ therefrom. The pad structure with spokes is exposed by way of an aperture formed through the solder mask such that the terminal pad and an inner portion of each of the spokes is exposed therethrough, and an outer portion of each of the spokes is covered by the mask. The Lee reference describes a solder ball pad structure having a terminal etching hole as well as a plurality of etching holes at the outer portion of the solder ball pad structure for increasing the contact area for a solder ball.

Please replace paragraph number **[0017]** with the following rewritten paragraph:

[0017] Another area of interest is the design flexibility in the number of circuit traces that may be operably positioned to run between two adjacent solder ball pads with adequate spacing between the traces and between the traces and the solder ball pads. More specifically, the aforementioned tolerance considerations, as well as the differences in the formation of SMD and NSMD solder ball pads, must be factored in determining the spacing between circuit traces

and solder ball pads. Of course, dimensional ~~tolerances~~ tolerances, as well as parameters required to achieve a robust ~~design~~ design, limit the ability to position additional circuit traces between solder ball pads for a given solder ball pad design pitch.

Please replace paragraph number **[0018]** with the following rewritten paragraph:

[0018] In view of the foregoing, a method for fabricating solder ball mounting pads on a substrate and resulting solder ball mounting pads which improve on both types of conventional solder ball pads and ~~eliminates~~ eliminate some of their respective disadvantages would be desirable.

Please replace paragraph number **[0020]** with the following rewritten paragraph:

[0020] The solder ball pad structure of the present invention may provide a variety of advantages. First, the lateral positional tolerance of an attached solder ball is largely determined by the tolerances associated with the formation of the solder mask, similar to the SMD solder ball pad. Additionally, the optional interface layer and subsequent metal layers which may be attached to the metal terminal pad enable the solder ball to attach to the vertical side surface of the aperture in the resulting structure, which configuration may provide enhanced thermal stress distribution in the solder ball connection. Also, the solder ball pad of the present invention ~~also~~ provides increased surface area for solder ball attachment, as well as an indented surface for attachment which may further strengthen the bond between a solder ball and the inventive solder ball pad structure.

Please replace paragraph number **[0042]** with the following rewritten paragraph:

[0042] Referring again to conventional practices to provide a more detailed basis for comparison with the present ~~invention~~ invention, and not in any way ~~in limitation of~~ to limit the scope thereof, FIG. 1A is a top view of a portion of a conventional SMD substrate 10 having a solder-mask-defined ("SMD") solder ball mounting pad 28 formed thereon. FIG. 1B is a cross-sectional view looking into the SMD substrate 10 and mounting pad 28 along the

lines IB--IB in FIG. 1A. The SMD substrate 10 may comprise a sheet 12 of an insulative material, such as bismaleimide triazine, flexible polyimide film or tape, fiberglass, polyimide tape, ceramic, or silicon, or, alternatively, ~~it~~ the SMD substrate 10 may comprise a semiconductor chip or die. The SMD substrate 10 typically comprises a layer of metal, e.g., copper, aluminum, gold, silver, nickel, tin, platinum, or a combination of the foregoing that has been laminated and/or plated on a surface of the ~~substrate~~ insulative sheet 12, then patterned using known photolithography techniques into a terminal pad 14, which may include one or more circuit traces 16 (shown by dotted lines) extending ~~from it.~~ therefrom. In addition to the circuit traces 16, a plated through-hole, called a "via" (not shown), may connect the terminal pad 14 with the opposite surface of the ~~substrate~~ insulative sheet 12 as known in the art.

Please replace paragraph number **[0043]** with the following rewritten paragraph:

[0043] An insulative layer in the form of solder mask 20 is formed over the metal layer, including the terminal pad 14. The solder mask 20 may comprise an acrylic or a polyimide plastic or, alternatively, an epoxy resin that is silk screened or spin-coated on the insulative sheet 12. A dry film solder mask may also be employed. An aperture 19 is formed in the solder mask 20 to expose a mounting pad ~~portion~~ 28 of the terminal pad 14, and a solder ball 24 (shown ~~dotted~~ in dotted outline in FIG. 1A) is attached ~~to~~ to, or formed ~~on~~ on, the mounting pad 28 thus exposed. Since the solder mask 20 prevents the solder of the solder ball 24 from attaching to any portion of the terminal pad 14 other than the mounting pad 28 that is exposed through the aperture 19, the mounting pad 28 is referred to as a solder-mask-defined or SMD-type of solder ball mounting pad, as described above.

Please replace paragraph number **[0045]** with the following rewritten paragraph:

[0045] As may be seen from a comparison of the two sets of figures, the respective mounting pads 28 and 28′ are very similar, the exception being the relative sizes of the apertures 19 and 19′ in the solder mask 20. In particular, in the NSMD mounting pad 28′ of FIGS. 2A and 2B, the aperture 19′ exposes the entire terminal pad 14, along with a portion of the

surface of the ~~substrate~~ insulative sheet 12 and a portion of the optional, adjacent circuit trace 16, such that the molten solder of the solder ball 24 can wet and attach to not only the entire upper surface of the terminal pad 14, but also to the vertical peripheral side surface 26 of the terminal pad 14 and the optional circuit trace 16. Along the vertical peripheral side surface 26 of the terminal pad 14, the solder ball 24 attaches and forms a curved attachment surface 29 with the vertical peripheral side surface 26 of the terminal pad 14.

Please replace paragraph number **[0047]** with the following rewritten paragraph:

[0047] FIGS. 3A and 3B show a top and side cross-sectional view of the BPS substrate 40 with solder ball mounting pad 36 according to the present invention. Solder mask 20 exposes an area of the terminal pad 41 on insulative ~~material~~ sheet 12 by way of aperture 23. Interface layer 38 is formed onto the exposed surface area of the terminal ~~pad~~ pad 41 as well as extending onto the vertical sidewall of the aperture 23 and onto the top horizontal surface of the solder mask 20. Interface layer 38 may be used to enhance the adhesion of the subsequent copper layer to the solder mask 20 surface, and may comprise an epoxy, such as HYSOL® EO1073 or EO1075, from Henkel Loctite Corporation, Connecticut. Interface layer 38 may optionally comprise a metal layer formed by using an electroless plating solution or a conductive polymer, as described in more detail below. Copper layer 48 is formed over the terminal pad 41 as well as interface layer 38, if present, thus extending along the horizontal portion of the terminal pad 41 and onto the sidewall of the solder mask 20 defining aperture 23, and also onto the horizontal top surface of the solder mask 20. Copper layer 48 may comprise an electroless copper seed layer (which may be the interface layer 38) followed by an electroplated copper layer or may be otherwise formed as known in the art. Further, nickel and gold layers, collectively shown as solderability enhancement layer 18 for clarity, may be applied to the copper layer 48 to enhance the wettability to solder of the resulting mounting pad surface. Nickel is used to prevent diffusion of copper to the solder ball pad surface and gold is used for solder wettability. Thus, optional interface layer 38, copper layer 48 and solderability enhancement layer 18 together comprise a solder ball pad layer 60.

Please replace paragraph number **[0048]** with the following rewritten paragraph:

[0048] Because the interface layer 38 as well as the copper layer 48 and solderability enhancement layer 18, due to their extension up the sidewall of solder mask 20 defining aperture 23 and over onto the outer surface of solder mask 20, may provide a larger surface area than the area that would be exposed by aperture 19 in a typical SMD-type solder ball pad, the size of terminal pad 41 of a BPS solder ball pad structure may be accordingly reduced. Stated another way, to achieve a final bonding area that is equal to a given SMD mounting pad area, the terminal pad 41 formed from the metal layer deposited on the surface of the ~~substrate~~ insulative ~~sheet~~ sheet 12 may be smaller than the terminal pad 14 of an SMD or NSMD configuration. Reducing the size of terminal pad 41 may allow for more lateral space between adjacent terminal pads to become available on the surface of insulative sheet 12. By way of example only, solder ball pad layer 60 may exhibit a diameter of about 0.33 millimeters or larger and a total surface area of about 0.05 square millimeters or greater.

Please replace paragraph number **[0050]** with the following rewritten paragraph:

[0050] Suitable and exemplary rigid insulative ~~sheet~~ sheet 12 materials ~~12 for~~ for a BPS substrate include BT832, MGC, MCL679, FR-4, FR-5 materials from Hitachi Co., Japan. Suitable and exemplary flexible insulative ~~sheet~~ sheet 12 materials ~~12 for~~ for a BPS substrate include polyimide layers or fibers such as UPILEX™ from Ube Industries Ltd., Japan, ESPANEX™ from Nippon Steel Chemical Co. Ltd., Japan, and KAPTON™ and MICROLUX™ commercially available from E.I. Dupont de Nemours Company, as well as Polytetrafluoroethylene (PTFE), and a liquid crystal polymer. It should also be noted that the term "sheet" as used herein encompasses not only a self-supporting structure but a layer of material supported on another structure.

Please replace paragraph number **[0052]** with the following rewritten paragraph:

[0052] FIG. 4A shows a conventional SMD substrate 10 configuration having two solder ball mounting pads 28, formed by apertures 19 defined by sidewalls 21 (FIG. 4B) of solder

mask 20 that expose solder ball mounting ~~pads~~ pads 28 of the terminal pads 14 formed on the ~~substrate~~ insulative sheet 12, respectively. The distance between terminal pads 14 as well as tolerances in positioning the terminal pads 14 may substantially influence the amount of space in which to position conductive traces 30 and 32 extending between solder ball mounting pads 28. The spacing between traces 30 and 32 is determined from a number of variables. The distance between the centers of the terminal pads 14, termed "solder ball pad pitch," the terminal pad diameter, the conductive trace thickness t, the number of conductive traces, the lateral tolerance in forming conductive traces 30 and 32 and terminal pads 14, as well as the solder ball pad design all may influence the spacing d that may be afforded for placement of conductive traces 30 and 32 in relation to the terminal pads 14 on the ~~substrate~~ insulative sheet 12. In addition, it is common for the trace thickness t to be equal to the spacing between the traces.

Please replace paragraph number **[0060]** with the following rewritten paragraph:

[0060] FIGS. 6A and 6B show a conventional NSMD substrate 11 wherein two traces 30 and 32 extend between the terminal pads 14. FIG. 6A shows apertures 19′ exposing the entire terminal pads 14, ~~terminal~~ the terminal pads 14 forming mounting pads 28′.

Please replace paragraph number **[0061]** with the following rewritten paragraph:

[0061] FIG. 6B shows a side cross-sectional view of the solder ball pad configuration shown in FIG. 6A, but also including an example of a solder ball 24 (not shown in FIG. 6A) attached to left-hand mounting pad 28′. The distance d between a terminal pad 14 and conductive trace 30, conductive trace 30 and conductive trace 32, as well as conductive trace 32 and a terminal pad 14 is shown. Distance d, the spacing between a trace and another trace or a trace and a terminal pad, is also commonly used as the trace width as well as the spacing distance between the vertical sidewall 21 of aperture 19′ and a terminal pad 14. In addition, in an NSMD-type substrate, it is common for the design rule to specify a clearance distance between a vertical sidewall of an aperture, for ~~instance~~ instance, vertical sidewall 21 of aperture 19′, and the nearest sidewall of a trace, for instance, conductive trace 30.

Please replace paragraph number **[0066]** with the following rewritten paragraph:

[0066] FIGS. 7A through 7L show different embodiments 99, 101, 103, 105, 107 and 109 for a BPS solder ball pad layer 60 of the present invention wherein the solder ball pad layer 60 comprises optional interface layer 38, copper layer 48 as well as solderability enhancement layer 18, but is shown as a single ~~layer 60~~ layer in FIGS. 7A through 7L for clarity. FIGS. 7A and 7B show embodiment 99 including a solder ball pad layer 60 configured generally in a circular area wherein the solder ball pad layer 60 includes an aperture 82 therethrough, exposing area 90 of terminal pad 41. Area 90 may include a solderability enhancement layer 18, although this is not shown for clarity. Thus, a solder ball attached to the BPS solder ball pad embodiment shown in FIGS. 7A and 7B may be affixed to the mounting pad 36, mounting pad 36 comprising area 80 of solder ball pad layer 60 including side surface 71 and exposed area 90 of terminal pad 41.

Please replace paragraph number **[0068]** with the following rewritten paragraph:

[0068] For example, ~~FIG.~~ FIGS. 7E and 7F show embodiment 103 including a solder ball pad layer 60 having a terminal aperture 82 exposing area 90 of terminal pad ~~41and~~ 41 and extending elements 81 configured as radially extending elements generally symmetrically arranged about aperture 23.

Please replace paragraph number **[0069]** with the following rewritten paragraph:

[0069] Also, as discussed hereinabove, since the centroid of the mounting surface of the solder ball pad influences the position of the solder ball, by employing the solder ball pad of the present invention, the solder ball pad layer 60 may be tailored to position solder balls as desired or to correct for inaccuracy in the placement of apertures in the solder mask 20. More specifically, in the case where solder mask placement is less precise than solder ball pad layer 60 formation, the solder ball pad layer 60 may be used to correct variances in the solder ball mask aperture placement. Thus, each aperture in a solder mask 20 could be measured against a desired placement, and then the solder ball pad layer 60 could be displaced in order to correct for the

deviation. Correction may occur prior to formation of the solder ball pad layer 60; thus, aperture 23 position may be determined prior to forming the solder ball pad layer 60 onto the substrate and the position of solder ~~ball~~ ball pad ~~layer~~ layer 60 corrected accordingly. Alternatively, the solder ball pad layer 60 of each mounting pad may be formed and then the solder ball pad layer 60 may be modified to position a solder ball in a desired position. For instance, laser ablation, selective etching, or other removal processes may be used to selectively modify the area of attachment of a solder ball pad, and thus adjust placement of a solder ball attached thereto.

Please replace paragraph number **[0074]** with the following rewritten paragraph:

[0074] Referring now to FIGS. 8A and 8B of the drawings, a first exemplary process flow for fabricating the inventive structure of the present invention as depicted in FIGS. 3A and 3B is illustrated. As shown in FIG. 8A, a polymer conductive adhesive forming optional interface layer 38 may be applied over solder mask 20 and into aperture 23. By way of example only, suitable conductive polymers in the form of isotropic epoxy adhesives 3880 and 3889 are available from Henkel Loctite Corporation, Connecticut. The polymer interface layer 38 may be applied by stencil printing to cover the surface of terminal pad ~~41exposed~~ 41 exposed through aperture 23, the sidewalls of solder mask 20 defining aperture 23 and the top horizontal surface of solder mask 20 to form a collar of the polymer around aperture 23. An electroplated copper layer 48 may then be formed over interface layer 38, followed by electroplating of a nickel layer 18a and a gold layer 18b together comprising solderability enhancement layer 18, all as shown in FIG. 8B. It is also contemplated that a metal interface layer 38 may be applied by stencil printing, followed by electroplating of the copper, nickel and gold layers.

Please replace paragraph number **[0075]** with the following rewritten paragraph:

[0075] Referring to FIG. 9 of the drawings, an optional interface layer 38 to enhance adhesion to the solder mask 20 may be applied in the form of a nonconductive ~~epoxy~~ epoxy, such as the aforementioned HYSOL®EO1073 and EO1075 compounds or other suitable ~~polymer~~

polymer, by stencil printing over the top surface of solder mask 20 surrounding aperture 23, leaving the exposed area of terminal pad 41 and the sidewalls of solder mask 20 defining aperture 23 free of ~~material~~ material.

Please replace paragraph number **[0076]** with the following rewritten paragraph:

[0076] In lieu of the use of a conductive or nonconductive polymer as an interface ~~process~~ process, flow may proceed along several different paths. Referring to FIG. 10A, a "coverlay" element in the form of a dry film photoresist 100 (positive or negative) may be applied over solder mask 20, patterned by exposure to a required wavelength of light through a mask, developed, and portions of the dry film surrounding and extending into aperture 23 removed to expose terminal pad 41 and define annulus 102 surrounding aperture 23. If a nonconductive polymer has been used for adhesion enhancement to solder mask 20, it may already be present on annulus 102. As shown in FIG. ~~10B~~ 10B, a copper seed layer 104, which may comprise a metal interface layer 38, may be electrolessly plated over the dry film photoresist 100 and into aperture 23, covering the exposed portion of terminal pad 41, which copper seed ~~layer~~ layer 104 may be augmented by ~~electroplating~~ electroplating, if desired. Dry film photoresist 100 is then stripped off mechanically or chemically as known in the art, removing with it the overlying copper and leaving the copper layer 48 within and surrounding aperture 23 contacting terminal pad 41 and extending from aperture 23 as a collar over the top surface of solder mask 20, as shown in FIG. 10C. A nickel layer 18a and a gold layer 18b may then be electroplated onto the copper layer 48 to form solderability enhancement layer 18 and complete the structure of solder ball mounting pad 36 as shown in FIG. 10D.

Please replace paragraph number **[0077]** with the following rewritten paragraph:

[0077] In another process ~~sequence~~ sequence, and referring to FIG. 11A, an optional nonconductive polymer interface layer 38 (not shown) may be applied to solder mask 20 in an area surrounding aperture 23. In either case, with or without the presence of optional nonconductive interface layer 38, an electroless copper seed layer 104, which may itself comprise

a conductive interface layer 38, may be applied over solder mask 20, into aperture 23 and over the exposed portion of terminal pad 41. A coverlay element in the form of a dry film photoresist 100 (positive or negative) may be applied over solder mask 20, patterned by exposure to a required wavelength of light through a mask, developed, and portions of the dry film surrounding and extending into aperture 23 removed to expose terminal pad 41 and define annulus 102 surrounding aperture 23 and exposing a portion of electroless copper seed layer 104, as shown in FIG. 11B. Copper may then be electroplated onto the exposed copper in annulus 102, over sidewalls of solder mask 20 defining aperture 23 and onto the exposed portion of terminal pad 41 to complete copper layer 48, as shown in FIG. 11C. Nickel layer 18a and gold layer 18b may then be electroplated to form solderability enhancement layer 18, again as shown in FIG. 11C. Dry film photoresist 100 may then be stripped off mechanically or chemically, as known in the art, and the underlying electroless copper seed layer 104 removed by a soft etch comprising an alkaline ammonia solution to complete the fabrication of solder ball mounting pad 36, as shown in FIG. 11D.